Optimisation of Design of Butterfly Valve to Improve its Performance - A Review

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Abstract -Buttery valve is a valve which can be used for isolating or regulating flow. A buttery valve typically consists of a metal disc formed around a central shaft, which acts as its axis of rotation. Operation is similar to that of a ball valve, which allows for quick shut off. As the valve's opening angle is increased from 0 degrees (fully closed) to 90 degrees (fully open), fluid is able to move readily flow past the valve. There are some problems in the operation of Butterfly valve. The major problem related with Butterfly valve is Pressure drop and Flow loss. Pressure drop occurs when disc is rotated from fully closed condition to fully open condition (from 0^o to 90^o by sub steps of 10^o), cavitation takes place at downstream of flow at backside of disc. So, automatically Flow loss is increased and its performance is reduced. This problem can be reduced by giving various shapes(Aerodynamic) to the backside of disc. Due to such design, fluid will easily flow over the disc. So, its performance can be improved.

Keywords- *Pressure Drop, Flow Loss, Cavitation, Aerodynamic Shape.*

I. INTRODUCTION

Butterfly valves are commonly used as control valves in applications where the pressure drops required of the valves are relatively low. A butterfly valve is valve a which can be used for isolating or regulating the flow closing mechanism takes the form of a disc. Operation is similar to that of a ball valve, which allows for quick shut off. Butterfly valves are generally favored because they are lower in cost to other valve designs as well as being lighter in weight, meaning less support is required.A butterfly valve is from a family of valves called quarter-turn valves. In operation, the valve is fully open or closed when the disc is rotated a quarter turn.

The major problem related with Butterfly valve is pressure drop and Flow loss. Pressure drop occurs when disc is rotated from fully closed condition to fully open condition (from 0^0 to 90^0 by sub steps of $10^{0.}$) cavitation takes place at downstream of flow at backside of disc. This problem can be reduced by giving various shapes (Aerodynamic) to the backside of the disc. In industries, design of disc may be completed by considering various features, objectives of design which we seen in introduction part.

II. LITERATURE REVIEW

Ghaleb Ibrahim et.al [1] discussed that the Numerical analysis technique has become popular and reliable method in design of butterfly valves. It is possible to visualize and observe the flow characteristics around the valve and to estimate its performance. A numerical simulation for flow of water past over a butterfly valve using commercial fluid dynamics software FLUENT, has been implemented. In the analysis, the positions of the disk were set to be 0° (fully opened), 20°, 30°, 55° and 75°. Velocity profile, pressure distribution, turbulence kinetic energy and turbulence intensity are the parameters used to present the characteristic of flow. From the results obtained, turbulence in flow starts at the edges of valve disc and gets growing according to the specified case. These vortices and circulation region are generated always in downstream region behind the valve disc. They are formed due to contact between higher and lower velocities paths. It was found that the flow has a small effect with increasing closing angle till it reaches 55°, where the flow around the valve started to become highly turbulent.

S. Y. Jeons et.al [2] manufactured the butterfly valves in various shapes but a fitting performance comparison is not made up. For this reason, they carried out numerical analysis of some kind of butterfly valves for water supply and drainage pipeline using commercial CFD code FLUENT, and made a comparative study of these results. Also, the flow coefficient, the loss coefficient, and pressure distribution of valves according to valve opening rate were compared each other and the influence of these design variables on valve performance were checked. Through flow around the valve disk, such as pressure distribution, flow pattern, velocity vectors, and form of vortex, they grasped flow characteristics. The experimental results shows that there was not much in the valve performance between the single disk type and the double disk type butterfly valve. However, the double disk type butterfly valve showed more complex flow pattern, recirculating eddies, at the rear of valve disk compared with the single disk type butterfly valve.

X.G. Song et.al [3] estimated that analyses and optimization are of special important in the design and usage of butterfly valves. For the analysis, finite element method (FEM) is often used to predict the safety of valve disc, and computational fluid dynamics (CFD) is commonly used to study the flow characteristics of valve. However, it is difficult to obtain accurate results for the optimization of butterfly valve due to the high non-linear ties. For this reason, metamodels or surrogate model methods are extensively employed. This integrates metamodel with FEM and CFD analysis to optimize a traditional butterfly valve, where the weight of the valve disc is the design objective, and the strength safety of disc and the pressure loss coefficient of valve are constraints.

Young Chul Park [4] has explained that three-dimensional numerical simulations by commercial code CFX were conducted to observe the flow patterns and to measure valve flow coefficient and hydrodynamic torque coefficient when butterfly valve with various opening degrees and uniform incoming velocity were used in a piping system. By contrast, a group of experimental data is used to compare with the data obtained by CFX simulation to investigate the validity of numerical method.

Lin Wang et.al [5] discussed that the fluid structure interface(FSI) analysis is carried out to estimate fluid field and performance of butterfly valve. A three-dimensional model of butterfly valve is used to do simulation perfectly. The FSI analysis not only analyzes the fluid field at various valve openings, but also verifies whether the valve can work safely under serious conditions or not. The result shows this type valve is not safe when valve is opened at various degrees or when valve is closed. To ensure that the valve can worksafely, the improvement of this valve is carried out. And some important dimensions of valve components are chosen to be assembledin different values. And the analyzed results of different assemblages are compared to determine the best one which can strengthen the structure and reduce the weight of valve mostly furthest.

Qin Yang et.al [6] discussed that the stop valves are commonly used as fluid flow control equipments in many engineering applications. Thus it’s more and more essential to know the flow characteristic inside the valve. Due to the fast progress of the flow simulation and numerical technique, it becomes possible to observe the flows inside a valve and to estimate the performance of a valve. The flow system with stop valves is complex structure and has non-linear characteristics, because the construction and the hydraulic phenomena are associated of stop valves. Three-dimensional numerical simulations were conducted to observe the flow patterns and to measure valve flow coefficient and flow fluctuations when stop valve with different flow rate and uniform incoming velocity were used in a valve system.

III. BUTTERFLY VALVE

In Butterfly valve, disc is closer member in the valve. The disc is positioned in the center of the pipe, passing through the disc is a rod connected to an actuator on the outside of the valve, as shown in fig. 1. Rotating the actuator turns the disc either parallel or perpendicular to the flow. Unlike a ball valve, the disc is always present within the flow, therefore a pressure drop is always induced in the flow, regardless of valve position.

In operation, the valve is fully open or closed when the disc is rotated a quarter turn. The "butterfly" is a metal disc mounted on a rod. When the valve is closed, the disc is turned so that it completely blocks off the passageway. When the valve is fully open, the disc is rotated a quarter turn so that it allows an almost unrestricted passage of the fluid. The valve may also be opened incrementally to throttle flow.

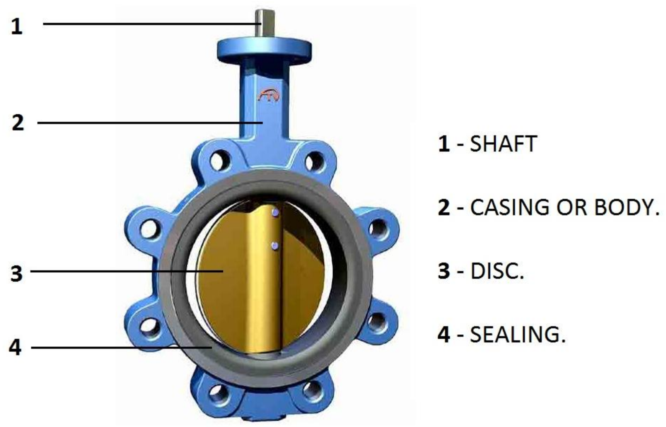

Figure 1: Basic Components of Butterfly Valve

IV. TECHNICAL REQUIREMENTS OF BUTTERFLY VALVE

Main purpose of the valves installed ahead of turbine is to close the penstock while the turbine is not in operating condition. Valve must possess high degree of reliability and durable strength at closed position so that trouble free operation can take place. It should also ensure the possibility of carrying out repair works, revisions of turbines, pumps, pressure penstock and at the same time to create lowest resistance to flow. Valve must close at velocity of water occurring during emergency cases (rupture of penstock or runway speed of turbine).Maximum time for closure of the valve when it is installed before the turbine pump is 1-3 minutes and depends upon the permissible time of operation of generator at run way speed and motor of the pump in generator regime. If the valve is installed at the beginning of the penstock, then its closure time will be in the range of 30-120 seconds. Time of closing of valve on sluice and irrigation schemes is determined from the operational conditions of these constructions. Minimum time of emergency closure is determined as per permissible value of hydraulic impact on penstock. Operation of spherical and b.f. valve is depend upon the extreme positions of the rotating part while in case of cylindrical valve it is accomplished at any position including extreme positions for regulating discharge of liquid through them is zero to maximum possible discharge. Servomotors of various designs are used to rotate the rotating element, by mechanical or electro mechanical drive

V. DESIGN OF DISC

` A buttery valve typically consists of a metal disc formed around a central shaft, which acts as its axis of rotation. The butterfly valve is similar in operating way to a ball valve. A disc is positioned in the center of the pipe typically and has a rod through it connected to an actuator on the outside of the valve as shown in figure 1. The actuator turns the disc either parallel or perpendicular to the flow to control the flow. Regardless of valve position, the disc of a butterfly valve is always positioned within the flow, therefore a pressure drop is always presented in the flow. Because fully opening the valve, the disc is rotated a quarter turn so that it allows the fluid to go through in an almost unrestricted passage.

However, there is a pressure drop limit (DPmax) which should not be exceeded or cavitation inside the valve anddownstream piping will occur. Cavitation occurs when the local velocityof the water becomes so high that the water vaporizes (flashes). As thewater vapor continues to move past the valve the velocity drops, and thevapor bubbles collapse causing very large pressure changes on the insidewalls of the valve and downstream piping. Cavitation can destroy a valveor the piping immediately downstream from the valve. The maximum allowable pressure drop for a butterfly valve be determined from the following equation:

$$DPmax = Km (Pi - 93Pv)$$

Where:

DPmax = Maximum Allowable Pressure Drop, psi

Km = Valve Recovery Coefficient,

Km (90°) = 0.32

Km (70°) = 0.5

Pi = Inlet Pressure, in psi

Pv = Water Vapor Pressure, in psi.

To avoid Cavitation and pressure loss, we can change the shape of disc e.g. Aerodynamic. as shown in fig. below.Different models will be developed by giving the various aerodynamic or streamlined shapes to downstream side of disc of the valve. Modeling will be done using CATIA software. Also we can use Butterfly valve with different arrangement of disc such as zero offset, double offset, triple offset Butterfly valves.

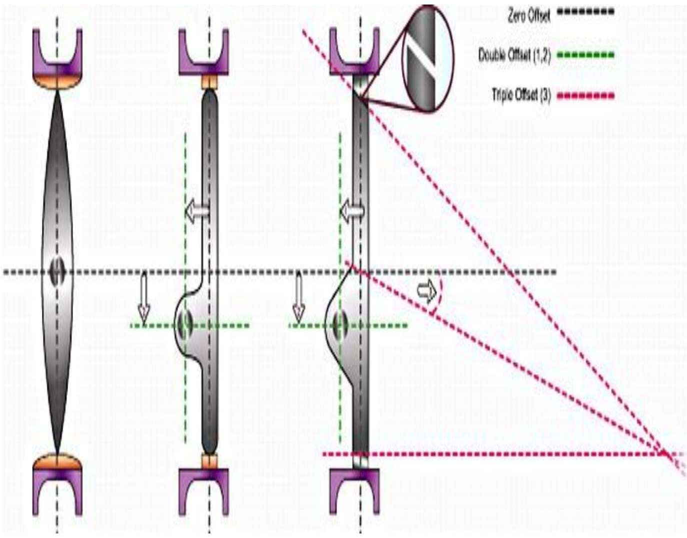

Figure 2: Offset Types of Butterfly Valve

A. Zero Offset

Concentric valve (zero offset). Disc rotates around the centre axis allowing for a potential 360º rotation. Sealing is achieved by the disc deforming the soft seal, resulting in full friction through the full operating cycle.

B. Double Offset

To allow displacement of the seat, the shaft is offset from the centre line of the disc seat and body seal (offset one), and the centre line of the bore (offset two). This creates a cam action during operation to lift the seat out of the seal resulting in friction during the first 10 degrees of opening and final 10 degrees of closing. double-offset disc design which allows the disc to move off the seat with a "camming" action, reducing break-away torque and seat wear. The 360° uninterrupted disc seal eliminates the leak path at the shaft hubs found on PTFE and rubber-lined valves. A strong Stainless Steel shaft encapsulated with graphite or fiberglass-reinforced vinyl ester resin eliminates corrosion and assures long trouble-free operation.

C. Triple Offset

The third offset is the geometry design of the sealing components, not the shaft position. The sealing components are each machined into an offset conical profile resulting in a right angled cone. This ensures friction free stroking throughout its operating cycle. Contact is only made at the final point of closure with the 90° angle acting as a mechanical stop; resulting in no over – travel of the disc seat.

VI. DESIGN BENEFITS

- The fluid will easily passed away over the disc of valve and the separation of flow will occur much behind the normal designs of disc, so the cavitation and pressure drop will be reduced.
- Loss of energy can be reduced.

- Weight of disc is reduced.

CONCLUSION

We seen the major problem related with Butterfly valve is pressure drop and Flow loss. Pressure drop occurs when disc is rotated from fully closed condition to fully open condition (from 00 to 900 by sub steps of 100.) cavitation takes place at downstream of flow at backside of disc. For improvement in performance of Butterfly valve, there is need to reduce this problems.

So we conclude that these problems can be reduced by giving various shapes (Aerodynamic) to the backside of the disc. Due to such design, pressure drop is reduced and also there is increase in flow. Automatically it increases the performance of Butterfly valve. Also we have seen how product design is done in industries.

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